Calibration of a Fast Field-Cycling NMR Relaxometer for Measurements on Biological Samples that Extend to Ultra-Low Magnetic Fields

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A graph of T_1 versus the applied magnetic field (known as a T_1-dispersion curve), obtained via Fast Field-Cycling (FFC) NMR and MRI techniques, can be developed into a new medical diagnostic tool thanks to the information about molecular motions that it provides. The extension of the techniques to ultra-low magnetic fields (below 10 kHz ^{1}H Larmor frequency) is expected to increase their potential, allowing for the study of much slower motions.

Compensation for the environmental fields acting on an FFC NMR relaxometer, necessary for ultra-low field applications, involves the application of FFC techniques along with optimised correction magnetic fields, with the acquired results shown as graphs that plot the measured resultant field B_r (composed of the correction and environmental fields) as a function of the correction field. The environmental fields are then measured by fitting a model to these data which expresses the relation of B_r to all of its components (Equation 1), and the compensation is achieved by adjusting appropriately the opposing correction fields.

$$B_r = \sqrt{(B_c^l + B_e^l)^2 + ((B_c^t \cdot \sin(\theta)) + (B_e^t \cdot \sin(\varphi)))^2 + ((B_c^t \cdot \cos(\theta)) + (B_e^t \cdot \cos(\varphi)))^2} \quad (1)$$

where B_c^l and B_c^t are the longitudinal and transverse components of the correction fields and B_e^l and B_e^t; are the longitudinal and transverse components of the environmental fields, and θ and ϕ their azimuth angles.

The applied correction fields, found by curve fitting (Fig. 1), lead to dispersion curves that extend to ultra-low magnetic fields. In the example shown in Fig. 2, calibration reveals a segment of different slope from the rest of the curve, indicating the occurrence of slow dynamic processes in tissues probed via ultra-low field FFC methods. The shape of the curves (at both low and high fields) needs further work to interpret, since they are likely to provide clinically relevant information and can form the basis of new types of contrast.

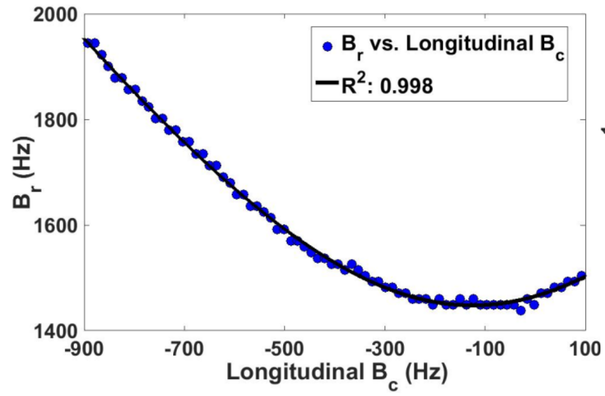

Figure 2. Graph of Br versus a longitudinal correction field.

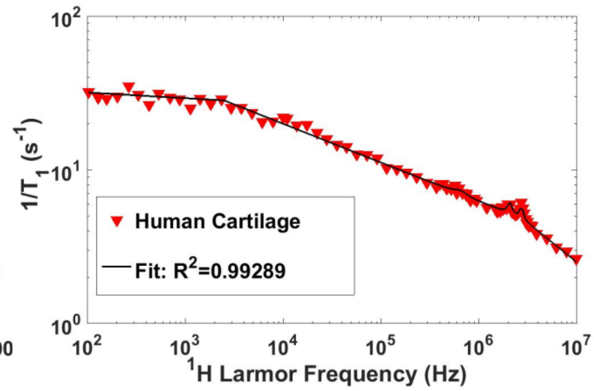

Figure 1. $1/T_1$-dispersion curve, obtained from a sample of human cartilage.